Instrument Hazard Analysis Document (IHAD)
Experimental Endstation: Momentum Imaging Spectroscopy for TimE Resolved Studies (MISTERS)

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Location of Work: 002-0102 and 002-0333
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Division: Chemical Sciences
Principal Investigator: Thorsten Weber (x5588)
Work Leader(s): Felix Sturm
Notes: none

Note: - This IHAD covers the development and operation of the MISTERS apparatus in the labs of building 2.

Description of Activity:
The Momentum Imaging Spectroscopy for TimE Resolved Studies (MISTERS) apparatus is an endstation, which is used for gas phase experiments at the high harmonics laser laboratories of the Ultrafast Xray Science Lab (UXSL). It is maintained and further developed in building 2, lab 102 and 333.

The setup is a vacuum system (operating pressures <1E-4mbar) and consists of I) a differential pumping stage, II) the main chamber, which has room for a two stage supersonic gas jet and a momentum spectrometer, and III) a chamber between the differential pumping stage and the main chamber where the high harmonics of the refocused laser beam is analyzed.

The differential pumping stage consists of two individually pumped sections with one aperture and two ~0.5 x 5in tubes, as well as ion gauges and an x-y collimator. The photon beam is back-reflected in the main chamber, refocused in the gas beam and then sent back to the high harmonics spectrometer chamber. The main chamber however is more complex. It has the following components (see “MISTERS_Sketch” in “Upload Files” of this AHD). In the source chamber the target gas gets introduced via a small nozzle (dia: 15 to 30 micron) using fore pressures up to 55bar (800 psi). The adiabatic expansion of the gas into the vacuum (1E-4mbar) forms a supersonic gas jet, which travels upwards through a small skimmer (0.25mm orifice) into the second stage chamber (1E-6mbar). This section collimates the gas beam and serves as a differential pumping stage for the target chamber which the gas beam enters after traveling through another skimmer (0.3mm orifice). In the target chamber (1E-9mbar) the gas jet intersects with the photon beam inside the momentum spectrometer, which is mounted in the center of the tank. The main part of the gas jet is sent to the two stage jet dump (1E-9mbar) after traveling trough two small aluminum tubes (~0.5 x 4in and ~1.0 x 4in long).

The spectrometer is equipped with two position and time sensitive Multi Channel Plate (MCP) detectors, with delay line readout at the two spectrometer ends. The charged particles (electrons and ions), which are created in the overlap region of the gas jet and the photo beam, are guided towards their detectors by weak electric and magnetic fields. From Time Of Flight (TOF) and the position of impact on the detectors, the 3D final state momenta of each particle can be determined in coincidence.

During the experiments the setup is closed and under vacuum. The gas jet is running, and the detectors, as well as the spectrometer and the Helmholtz coils (which generate the magnetic field) are supplied with DC electric power. The detector signals are decoupled from the vacuum feedthroughs and fed into electronic NIM modules. Two small sets of Helmholtz coils (named rainbow coils) are mounted to compensate the earth's magnetic field – both vertically and horizontally

This IHAD lists only the significant hazards associated with this activity. Significant hazards are those which; are elevated from a technical activity that requires specialized training and experience beyond that of a normal practitioner to conduct safety; and the risk of exposure to the hazards is sufficient to require that the hazard be mitigated.

This IHAD will be updated annually or whenever new significant hazards are introduced.

Identification of Hazards and Mitigations:

While maintaining and operating the MISTERS apparatus the following hazards are present:

Schedule: Electrical - High Voltage / Low Current

1) Description of Hazard
The detectors and the spectrometer are supplied with high voltage (up to 4kV) via home-made decoupling boxes and voltage dividers. High voltage and low current electric power supplies (output: 4kVDC, 3mA) are used to operate the setup.

2) Controls
a) Mitigation of Hazards
High voltage exposed elements are shielded by the vacuum chamber and cannot be reached in operation. The chamber frame as well as every single box needs to be grounded with the supplied cables before use. Only SHV-SHV, BNC-BNC, and LEMO-LEMO cables are used. During operation the electronic boxes must be closed. No voltage higher than 4kV shall be applied. The home-made boxes were presented to and inspected by the LBNL electrical safety Manager Keith Gershon; in case of any queries do not hesitate to contact him before you use the equipment.
b) Personal Protective Equipment (PPE)
No special personal protective measures are necessary for protection. Wear the standard lab PPE (Personal Protective Equipment), as listed at the lab entrance. For soldering work the use of a fan to deflect hazardous fumes is recommended. Lead based soldering tin has to be handled with gloves. Safety glasses or goggles must be worn. See "Safe_Soldering" in the "Upload Files" of this AHD.

3) Emergency Procedures
Turning the high voltage power supplies off eliminates any hazards.

4) Maintenance
In the event maintenance or repair is needed, a visual spark test may be inevitable. In this case define and close off a test area, where high voltage can be applied safely, while the box is open and grounded or the spectrometer and the detectors are accessible. Perform the spark test with a collaborator and keep a distance of 1 m (or 3 feet), while voltage is applied. Turn off the power supplies and disconnect the cables before touching the components.

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5) Training
EHS0243, EHS0260, ENG1001

Schedule: Electrical - Low Voltage / High Current

1) Description of Hazard
The Helmholtz Coils are supplied with low voltage and medium high current. They are operated from a low voltage medium current power supply (output 48VDC, 40A).

2) Controls
a) Mitigation of Hazards
The Helmholtz Coils connection is realized in a metal box to avoid direct contact and electric shortening. Do not remove this cover while the coils are operating. Since the negative voltage supply is set to ground the Helmholtz coils have extra grounding cables which need to be connected to the (grounded) vacuum chamber before applying power. Do not block the power supply fans and air outlets. Otherwise the supply will overheat and malfunction. If possible, use cable bridges to isolate the bulky AC connection cable, and to prevent trip and fall incidents. The home-made Helmholtz Coils were presented to and inspected by the LBNL electrical safety Manager Keith Gershon; in case of any queries do not hesitate to contact him before you use the equipment.
b) Personal Protective Equipment (PPE)
No personal protective measures beyond standard PPE, as mandated at the entrance to the laboratory or experimental area, are necessary.

3) Emergency Procedures
Turning the power supply off eliminates any hazards.

4) Maintenance
In the event of malfunction, the power supply has to be repaired by trained technicians only. Maintenance of the connection of the cables to the Helmholtz Coils can be done when the power supply is disconnected from the coils; turn off the power supply first. The covers of the boxes must be reinstalled before turning on the power again.

5) Training
EHS0243, EHS0260, ENG1001

Schedule: Electrical – Medium Voltage / Medium Current

1) Description of Hazard
Two small sets of Helmholtz coils (a.k.a. rainbow coils) are mounted vertically and horizontally to compensate the earth magnetic field. They are supplied with low power by using a low voltage, medium current power supply (output: 30VDC, 3A). A Rainbow Coil set is made from computer data cable. The special connection of the 50 x AWG 28 cables results in 2 parallel coil pairs. Each pair is connected in series. The vertically and horizontally–orientated coils have an overall resistance of 12 Ohm per direction. Thus the equivalent circuit represents 2 AWG 22 coils in series, i.e., 1 Helmholtz coil pair, for each direction (horizontally and vertically).

2) Controls

a) Mitigation of Hazards
Operation with a laboratory DC power supply (30 VDC, 3 Amps) will meet the current limits of the AWG 22 coils. Do not apply any voltage higher than 30 VDC.
b) Personal Protective Equipment (PPE)
No personal protective equipment beyond standard PPE, as mandated at the entrance to the laboratory or experimental area, is required.

3) Emergency Procedures
Turning the voltage power supply off eliminates any hazards.

4) Maintenance
Disconnect the rainbow coils from the power supply before any maintenance work.

5) Training
EHS0243, EHS0260, ENG1001

Schedule: Magnetism - High Fields

1) Description of Hazard
The Helmholtz Coils can generate an up to 20 Gauss magnetic field. State of the art pace makers should not be affected by a constant magnetic field, however caution should be exercised with older models (<1970). However, the magnetic field might be strong enough to erase data on credit or debit cards and affect other magnetic strip cards such as bus and subway tickets (BART). It can also damage your watch or computer monitor. Please see the **"Appendix: Magnetic Field Hazards"** to get detailed information about the harmful effects of magnetic fields.
The Rainbow Coils can generate a magnetic field up to 1 Gauss and are thus harmless.

2) Controls
a) Mitigation of Hazards
The magnetic field will be measured by a safety officer prior to the start of an experiment. From this measurement the nominal hazard distance (5 Gauss demarcation line) will be determined and marked off.
b) Personal Protective Equipment
No personal protective equipment beyond standard PPE, as mandated at the entrance to the laboratory or experimental area, is required.

3) Emergency Procedures
Turning off the power supply eliminates any hazards.

Schedule: Cryogenics Usage - Cold Traps

1) Description of Hazard
In order to improve the vacuum in the target chamber a cold trap (approx. 4 liters liquid N_2) is implemented in the chamber as part of the Titan Sublimation Pump (see "MISTERS_Sketch" in the "Upload Files" of this AHD). A factor of 3 less in residual gas pressure can be expected by filling the trap with liquid nitrogen.

2) Controls

a) Mitigation of Hazards
LBNL cryogenic safety protocols, as per Pub 3000, will be followed. Do not overfill the trap. Make use of the supplied and insulated funnel. In the event the trap needs to be emptied, pressurized warm air can be fed in via the supplied metal spout, which has an insulated handle bar and a high pressure hose attached to it. Do not touch the metal suction spout after removal (note: it will be on LN_2 temperature, i.e. 80K).
Since the volume of the trap is rather small, it is advised to fill the reservoir slowly and in subsequent steps when it is warm; this will avoid splashes and spills.
b) Personal Protective Equipment (PPE)
As a general rule, operators shall wear protective eyewear with side shields (or goggles) when working with cryogens. A face shield is optional when filling the traps. A face shield and gloves must be worn over the safety glasses or goggles when filling a Dewar at a pressurized cryogenic source tank. Always wear closed toed shoes and long pants.

3) Emergency Procedures
Call 7911 or 911 in case of any serious injury.

4) Maintenance
The Dewar vessels are inspected regularly for any damage or leaks; the Personal Protective Equipment is inspected regularly for damage and wear and tear.

5) Training
EHS0170, EHS0171

Schedule: Heavy Lifting – Crane Operation

1) Description of Hazard
The first stage of the super sonic gas jet (125kg or 250lbs) is removable and needs to be opened in case the nozzle is clogged or needs to be changed. For this reason a removable manual crane mounted on an aluminum post, which is attached to the chamber frame, is provided. Before using the crane make sure the vacuum chamber sits on its feet only. Since the crane is made out of (magnetic) steel, it needs to be removed during data taking. The crane post can be adjusted in height to a certain degree and may rest on blocks (such as tape wrapped or coated/painted lead bricks for instance) in order to match the height of the chamber, which varies with different laser tables. Besides off-the-shelves nylon slings, two types of customized lifting gear can be used to lift the load: a.) the 8020 spreader beam (see “Spreader_Bar” in the “Upload Files” of this AHD) with attached cables and chains or b.) the preassembled lifting ring with four shackles and chains. Do not temper or disassemble this load tested equipment. It is not recommended to use these parts for any other purposes.

2) Controls
a) Mitigation of Hazards
Since the crane is a bulky tall object it is recommended to take it on and off the post with two people. The operation of the crane is allowed by trained personal only (EHS0210). During operation, no personal under the load is allowed at any time, unless the lid is properly secured.
b) Personal Protective Equipment
No personal protective equipment beyond standard PPE, as mandated at the entrance to the laboratory or experimental area, is required. However additional personal protective equipment such as helmet, sturdy work gloves, and steel toed shoes are recommended.

3) Emergency Procedures
In case the crane fails, and the load drops, do not try to reach in and catch it. Call 7911 or 911 in case of any serious injury.

4) Maintenance
Before the first operation of the crane on a particular day the setup has to be inspected; using the provided checklist and logbook tied to the post. Every additional appropriate trained operator has to check the equipment again and must sign as well. These logs are kept in the logbook. Also the crane is inspected by trained and authorized LBNL personal twice a year; the inspector updates the tag near the handle – do not operate the crane if this tag is not up to date.

5) Training
EHS0210, EHS0062

Schedule: Heavy Lifting – Load Support

1) Description of Hazard
The first stage of the supersonic gas jet may need to be lifted but cannot be removed. In the event people now need to work under the lid, the load has to be securely supported.

2) Controls
a) Mitigation of Hazards
Use the provided aluminum frame and screw it on the chamber flange; the load can rest securely on this frame. Make sure to strap on the load to the frame with the provided straps. This frame has been approved by a LBNL engineer and shall be used exclusively (see "Jet_Support_Frame" in the "Upload Files" of this AHD). Make sure the frame is securely fastened and the load is correctly positioned on the frame. It is recommended to leave the load attached to the crane as well, while the load rests on the aluminum rods.
b) Personal Protective Equipment
No personal protective equipment beyond standard PPE, as mandated at the entrance to the laboratory or experimental area, is required. However (if possible) additional personal protective equipment such as helmet, sturdy work gloves, and steel toed shoes are recommended.

3) Emergency Procedures
Call 7911 or 911 in case of any serious injury.

4) Maintenance
Before use, inspect the aluminum frame visually for any damages. Do not use them if it is broken. Do not work under the load without this frame.

5) Training
EHS0210, EHS0062

Schedule: Heavy Lifting – Ergonomics

1) Description of Hazard

The MISTERS apparatus is a transportable setup and is under constant development and use. This means heavy components and equipment such as flanges, lead bricks, pumps, and gas cylinders etc. have to be moved and mounted frequently.

2) Controls

a) Mitigation of Hazards

Worksmart Ergonomics training (EHS0062) is required. The use of lab jacks, supporting blocks and frames, carts and pallet jacks to lift and transport equipment is advised. Gas cylinders (>4 liters) have to be transported strapped to dedicated gas cylinder carts, with the pressure regulator unmounted and the protective cap screwed onto the gas cylinder. The chamber is on wheels and can be moved that way; however it is highly recommended to use a pallet jack to transport the setup in hallways or to other buildings. Before transportation make sure the chamber feet are up all the way. The differential stage including the high harmonics spectrometer chamber can be detached from the main chamber and transported separately; preassembled adjustable lifting feet on wheels are available and just need to be attached on the 8020 frame.

b) Personal Protective Equipment (PPE)

No personal protective equipment beyond standard PPE, as mandated at the entrance to the laboratory or experimental area, is required. However additional personal protective equipment such as sturdy work gloves and steel toed shoes are recommended.

3) Emergency Procedures

Call 7911 or 911 in case of any serious injury.

4) Maintenance

Inspect (gas cylinder) carts, pallet jacks, lab jacks etc. before using them.

5) Training

EHS0062, EHS0171

Schedule: De/Pressurized System – Vacuum chamber

1) Description of Hazard

In order to perform the experiments, the MISTERS setup has to be evacuated. Three main parts of the main chamber, i.e. the source chamber, the second stage, and the target chamber have to be pumped down and evacuated simultaneously. Pressure differences have to be balanced.

2) Controls

a) Mitigation of Hazards

The different sections of the setup are connected via bypasses (see “MISTERS_Sketch” in “Upload Files” of this AHD), which can be found on the pump cart. These bypasses shall be opened during the pump down and venting phase in order to handle pressure differences between the three different sections of the setup and protect the skimmers of the gas jet system from damage. The viewports of the apparatus, which may implode in the event of any damage or failure, while the chamber is under vacuum, shall be covered with separate protective quartz glass windows or custom made spring loaded aluminum discs whenever possible.

If the gas supply lines of the supersonic jet fail or leak inside the chamber, the setup may experience excess inflow of gas from the gas cylinders. The excess gas flow rate is low enough so that it can be pumped out by the system vacuum pumps. In addition, a pressure relief valve is mounted on the source chamber in order to prevent over pressurizing the apparatus.

b) Personal Protective Equipment (PPE)
No personal protective equipment beyond standard PPE, as mandated at the entrance to the laboratory or experimental area, is required.

3) Emergency Procedures
Call 7911 or 911 in case of any serious injury.

4) Maintenance
All vacuum components and pumps shall be visually inspected for obvious damage (such as kinks and holes etc.) before pumping down the system after moving or changing the equipment or any long breaks in operation.

5) Training
EHS0171

Schedule: Compressed Gas, Flammable, Oxidizer – Gas jet

0) List of Gases
A file listing the current gases used in the MISTERS experiments and hazard analysis for components is available in the "Upload Files" section of this AHD: please see the file "List_of_Gases_and_Hazards". In the file Tables listed as follows are included.
Table 1: Gas Cylinder (Complete for ALL gases including inert gases).
Table 2: Gas Hazards (Complete for Flammable or Pyrophoric gases only).
Table 3: Accidental Release Analysis (Complete for Flammable or Pyrophoric gases only).
Table 4: Gas Hazards (Complete for Health Hazard gases only).
Table 5: Accidental Release Analysis (Complete for Health Hazard gases only)
Updates to these files will be made whenever new components are introduced or when listed components are no longer used. The Appendix located file will reflect current operating conditions. If the changes made in the updated file content do not result in any increase in hazard, no new authorization will be necessary. Determination of changing hazard level by a new item will be made by considering whether the hazard rating -HIGH or EXTREME- is sufficient to mandate a complete reauthorization.

1) Description of Hazard
The primary hazard in this setup is the accidental release of the supply gas for the experimental gas jet into the room and the inadvertent mixing of gases in the manifold (see "MISTERS_Gas_Manifold_Sketch" in the "Upload Files" of this AHD). The gas manifold system allows connecting up to 3 gas cylinders at the same time to the supersonic gas jet of the MISTERS apparatus. The objective is to make switching between the different gases easy and quick. Special locking valves are provided to prevent the inadvertent mixing of gases in the manifold. There are two possible release scenarios: leaks from the gas jet supply lines and manifold, or leaks from the vacuum system pump exhaust.

2) Controls
a) Mitigation of Hazards
The experimental gas jet will primarily be operated using nonhazardous gases. In this case, no special hazard mitigation beyond standard safe gas handling procedures will be necessary.
An administrative (lockout) procedure called "MISTERSGasManifold", which is available in the "Upload Files" section of this AHD, is in place to avoid mixing of incompatible gases and

minimize accidental release of hazardous gas into the environment. If hazardous (toxic or flammable) gases are used, we will use the following mitigation procedures:
1. Gas supply:
The preferred approach will be to use the minimum size gas cylinder necessary for the experiment. Gas cylinders with sufficiently small volume may be used without a gas cabinet, as long as the total used gas volume is below the limits allowed for the used gas (see table 1a in Appendix). This reduces the maximum possible exposed gas volume. If larger gas cylinders are used, a gas cabinet will be used to contain the cylinders. (The volume restriction on gas cylinder size in section 1a-Appendix, still applies). The cabinets will be vented to the building exhaust. The gas line from the gas cabinet to the gas jet input (external to the cabinet) must be leak checked before use, and kept to a minimum practicable length.
2. Gas exhaust:
Exhaust lines from pumps connected to the vacuum system will be vented to the building exhaust. The gas pressure in the vacuum system will be periodically checked for system integrity.

b) Personal Protective Equipment (PPE)
Standard PPE must be used, as mandated at the entrance to the laboratory or experimental area.

c) Hazardous Material Handling
The gas cylinders with hazardous gases will only be opened after proper secure mounting, and connection to a leak checked gas line system (incl. manifold). All gases will be handled using safe gas handling procedures. Used gas cylinders will be returned to the vendor, if possible. Contact EH&S for proper disposal procedures if you have cylinders, which contain hazardous gases and are nonreturnable.

3) Emergency Procedures
Call 7911 or 911 in case of any serious injury.

4) Maintenance
All high pressure lines, vacuum components and pumps shall be visually inspected for obvious damage (such as kinks and holes etc.) before pumping down or pressurizing the system after moving or changing the equipment or any long breaks in operation. Make sure not to tamper with the manifold when the gas bottles are attached to the gas inlets; note: only locking the valves is not sufficient – the gas lines have to be properly vented and the bottles have to be detached (for explanation see “MISTERS_Gas_Manfiold” in the “Upload Files” of this AHD); however, in case the gas line is attached to a gas cylinder inside a gas cabinet never open the gas line at the manifold before disconnecting the gas line from the regulator inside the gas cabinet first.

5) Training
EHS0171

6) Waste
When hazardous gases are used, all forepumps exhausts and the manifold outlet must be connected to the building exhaust.

Schedule: Seismic Safety

1) Description of Hazard
The MISTERS setup weighs about 700kg or 1400lbs and is about 7 feet tall. During an earthquake the apparatus could move randomly or even tip over.

2) Controls

a) Mitigation of Hazards

In order to prevent the MISTERS setup from moving or tipping during an earthquake, the chamber has to sit on 4 support feet, which are securely hold to the ground by specially designed brackets. These brackets are approved by a LBNL engineer. Since these brackets are fastened to the ground with screws, which are embedded in the floor, there is only one position in the lab where the apparatus can be kept safely for long times. It is recommended to put cones on top of these brackets when the setup is moved out of the room, in order to prevent trip and fall incidents. The electronics rack needs to be fastened to the ground with the two threaded rods on the side. The pump cart has to be secured using the unistrut bar and the two threaded rods.

b) Personal Protective Equipment (PPE)

While fastening the chamber to the floor and dealing with the edgy brackets or unistrut bar, the use of sturdy work gloves is recommended. As always, wear the standard PPE as listed at the laboratory entrance or the experimental ALS area.

3) Emergency Procedures

Call 7911 or 911 in case of any serious injury.

4) Maintenance

The brackets and bar are checked visually for any damage before use. The components have to be replaced in case of any impairment.

Schedule: Thermal - Heater tapes

1) Description of Hazard

Heater tapes are routinely used for high vacuum bake out. Heater tapes are connected to power sources through Variac's (fuse protected power adjustment adapter).

2) Controls

a) Mitigation of Hazards

Do not cross heating tapes. Use special adhesive tape to keep the heater tapes in place. Cover the heating tapes with Aluminum foil. Make sure to connect only heating tapes with similar resistance to one Variac. Do not combine more than 3 tapes. It is recommended not to combine Variac's via multiple outlets in order to prevent overloading power outlets. In case of a new combination of heater tapes and Variacs, start the heating process in ascending steps until you have reached and stabilized the desired temperature. Monitor the temperature with appropriate sensors. Use warning signs to prevent others from touching the hot surfaces. It is advised to hang a sign on the outside of the laboratory to inform others about the bake out process.

b) Personal Protective Equipment (PPE)

Besides the standard PPE as listed at the laboratory entrance or the experimental area, the use of sturdy work gloves or protective rubber gloves is recommended, in order to prevent cuts and skin irritation, during installation of the heating tapes. Use heat resistant gloves when you need to move the tape while it is warm. Do not touch the hot tapes with your bare hands

3) Emergency Procedures

Call 7911 or 911 in case of any serious injury. See the health personnel in building 26 for minor injuries. Cool burns with cold water while waiting for help.

4) Maintenance
Check the heating tapes before installation: Measure the resistance before and after installation (measure the resistance to ground as well).

5) Training
ENG1001

Schedule: Miscellaneous

Please be aware or reminded of these hazards when you deal with the following items:

- **Pumps:** The pumps are warm and noisy. Do not position the pumps next to heat sensitive equipment. Use earplugs or earmuffs or even combine them if you feel uncomfortable (please note that you have reached 90dB once you have to raise your voice in order to communicate with a person 3feet or 1m away from you; it is highly recommended to wear hearing protection then). Training is recommended (EHS0273 – Noise Exposure Awareness)
- **Power cords:** Many power cords and multiple outlets are needed in order to supply all pumps, controllers, electronics, and computers with electricity. Do not "daisy chain" multiple outlets and combine extension cords. That means do not form webs, nor do they loop back from the last device to the first. Please avoid trip and fall hazards dealing with these many power cords and cables; make use of cable bridges if possible or tape lines to the floor. The same applies to gas lines as well.
- **Electrical equipment:** Please make sure to ground the following (electrical) equipment before use: Electronic & controller racks, decoupling boxes, voltage dividers, chamber frame
  (ENG1001 - Electrical Safety and EHS0260 - Basic Electrical Hazards and Mitigations).
- **Gas cylinders:** Gas cylinders must be seismically secured. If there is no mounting frame available restrain the bottle in a gas cylinder cart, which is inhibited from moving by wooden chocks. When no gas line is connected to the gas cylinder, remove the regulator and protect the main valve with a cylinder cap, which is screwed onto the bottle (EHS0171 - Compressed Gas and EHS0170 - Cryogen Safety).
- **Ladders and stepstools:** If you want to use a ladder or step stool higher than 3feet or 1m, safety training is required (EHS0278 – Ladder Safety). You need training if a scaffold is higher than 3feet or 1m (EHS0279 – Scaffold Users Hazard Awareness).

Appendix: Magnetic Field Hazards

Guidelines for continuous exposure to static electromagnetic fields:
Note: 1 Gauss (G) = 0.1 millitesla (mT)

5 G	Highest allowed field for implanted cardiac pacemakers.
10 G	Watches, credit cards, magnetic tape, computer disks damaged.
30 G	Small ferrous objects present a kinetic energy hazard.
600 G	Allowed TWA for routine exposure (whole body).
6000 G	Allowed TWA for routine exposure (extremities).
20,000 G (2T)	Whole body ceiling limit (no exposure allowed above this limit).

50,000 G (5T)	Extremity ceiling limit (no exposure allowed above this limit).

Note: TWA exposure time is normally only a concern for extremely high field exposures to the whole body.

Explanation: Persons wearing metallic implants, such as bone or articular prostheses, surgical clips, nails or screws in broken bones, body piercing, or even dental fillings may feel painful sensations, if exposed to high magnetic fields. Persons fitted with pace-makers encounter a specific risk as static or pulsed magnetic fields may influence the working order of their pace-makers. Please see the following explanatory notes:

Metal associated with vessels

There is a potential danger of ferromagnetic hardware being displaced by the strong magnetic field. Coronary (heart) stents are MRI safe. Most carotid (neck) vascular clamps are safe at 1.5T (except Poppen-Blaylock clamp) but untested at 3T. Stents become firmly attached to tissues, and are unlikely to move beyond first few months. You can identify the exact device and see if it is listed as safe at http://www.mrisafety.com/

Other metal in the body

Metal bullets/shot/shrapnel in the head or torso should avoid kilogauss exposures. The only exception to this is implanted dental work in place for more than 6 weeks. Longstanding immobile bullets/shot/shrapnel in bones in the limbs are not a contraindication.

Non-removable piercings

We recommend that users should not be exposed to high magnetic fields with piercings in place as there is a small risk of heating, vibration or discomfort. Any unpleasant sensations/adverse reaction (pain, heating, vibration of piercing) must be reported to Health Services.

CSF shunts

Some are programmed magnetically, and will need the unit to be reprogrammed by their doctor after high field exposure

Tattooed eyeliner, tattooed eyebrows or Bigen hair dye

One may feel pain, heating, tactile sensations in the tattoo (and complete a peripheral nerve stimulation form if tactile sensations are experienced). Any unpleasant sensations / adverse reaction must also be reported.

Transdermal delivery patch (e.g. nicotine, contraceptive or medicated pain relief patch)

These may cause local heating. Remove before kilogauss magnetic field exposure.

Hearing aids & dentures (and removable bridge)

Remove before entering a high magnetic field.

Projectile Hazard

A danger frequently encountered comes from loose Ferro-magnetic objects present in a static magnetic field. If the field is strong enough, it will attract such objects from quite a distance and cause them to fly along the field lines towards the magnet. Watch out for any Ferro-magnetic objects you may carry in your pockets. Particularly objects with sharp edges may become dangerous projectiles. The use of Ferro-magnetic objects shall therefore be excluded from any high magnetic field. Non-Ferro-magnetic tools are available commercially.

Dynamic magnetic fields cause induced voltages, and the resulting currents either cause heating of metallic objects or disturbances in the human nervous system.

Controls:

Before you work near or in an area which has a high magnetic field ask yourself and your coworkers the following questions:

For exposure to magnetic fields of several hundred or several kilo Gauss
Absolute contraindications to entering the Magnetic field

- Do you have a heart pacemaker?
- Is there a possibility of metal in your head? (e.g. aneurysm clips, do not include dental work)
- Is there a possibility of metal in your eyes or have you ever needed an eyewash having worked with metals?
- Do you have an implanted medical device? (cochlear implant, metal ear tubes, bone stimulator, insulin or other medication pump, automatic defibrillator, internal pacing wires).
- Have you had any metallic dental implants (posts, crowns) within the last 6 weeks?
- Have you had any bone, tendon, spine or joint surgery within the last 6 weeks?

Potential contraindications to entering high magnetic field

- Do you have an IUD that may contain copper, or a contraceptive diaphragm?
- Have you had any stents, clips or surgery to any of any of your vessels (carotid artery vascular clamp, coronary stent, aortic clips, IVC filter, coils for blocked arteries)
- Do you have metal anywhere else in your body? (spinal rods, dental work, piercings, shrapnel, buckshot, bullets)
- Do you have any piercings that can't be removed?
- Do you have a cerebrospinal fluid (CSF) shunt? (treatment for hydrocephalus or water on the brain)
- Do you have tattooed eyeliner, tattooed eyebrows or Bigen hair dye?
- Do you wear a hearing aid or dentures?

Your best protection is to keep your distance to magnetic fields and their sources. Magnetic fields drop fast with distance. Try to stay behind the 5 Gauss demarcation line.

The 5 Gauss line is a demarcation between uncontrolled and control area. Similar to an ionizing radiation control area.

- Less than 5 Gauss no controls or posting required.
- Greater than 5 Gauss the pacemaker/electronic implant warning criterion
- 10-30 Gauss where credit cards, BART card stripes can be erased
- 30 Gauss projectile hazard starts
- At 600 gauss the time weighted average exposure takes over

Users and Training

Training:

The following training courses are **required**

Course #	Description	Weblink
ALS1001*	Safety at the ALS	http://ehswprod2.lbl.gov/coursebuilder/course/courselogin.aspx?cid=77&sid=959
ALS1005*	Access to the ALS	http://ehswprod2.lbl.gov/coursebuilder/course/courselogin.aspx?cid=94&sid=1181
EHS0062	Worksmart Ergonomics	http://www.lbl.gov/ehs/html/training_pdf/EHS62.pdf
EHS0170*	Cryogen Safety	https://ehswprod.lbl.gov/ehstraining/TrainingLogin/login.aspx?course=EHS0170&url=http://www.lbl.gov/ehs/training/webcourses/EHS0170
EHS0171*	Compressed Gas	https://ehswprod.lbl.gov/coursebuilder/course/courselogin.aspx?cid=186&sid=2580
EHS0243*	Soldering Awareness	https://ehswprod.lbl.gov/ehstraining/TrainingLogin/login.aspx?course=ehs0243&url=http://www.lbl.gov/ehs/training/webcourses/EHS0243/
EHS0260*	Basic Electrical Hazards and Mitigations	https://ehswprod.lbl.gov/ehstraining/TrainingLogin/login.aspx?course=ehs0260&url=http://www.lbl.gov/ehs/training/webcourses/EHS0260/
EHS0348*	Chemical Hygiene and Safety	https://ehswprod.lbl.gov/ehstraining/TrainingLogin/login.aspx?course=ehs0348&url=http://www.lbl.gov/ehs/training/webcourses/EHS0348/
EHS0470*	General Employee Radiation Training	http://ehswprod.lbl.gov/EHSTraining/GERT/default.asp
ENG1001*	Electrical Safety	https://ehswprod.lbl.gov/coursebuilder/course/courselogin.aspx?cid=66&sid=694

Courses marked with * are available online.

The following training courses are **recommended**

Course #	Description	Weblink
EHS0273	Noise Exposure Awareness	Call x6266
EHS0278	Ladder Safety	http://www.lbl.gov/ehs/html/training_pdf/EHS278.pdf
EHS0279	Scaffold Users Hazard Awareness	http://www.lbl.gov/ehs/html/training_pdf/EHS279.pdf

Users will receive additional on the job training: see "Upload Files" section of this IHAD

Authorization Signoffs:

Name	Role	Signoff Date
Ali Belkacem	Divisional Deputy Director (Designee)	
David Rodgers	Review Team Lead	
Jerome Bucher	CH Division Safety Coordinator	
Thorsten Weber	Principal Investigator	

User Signoffs:
For detailed training information, see IHAD web application.

Name	User Type	Access Type	Tasks	Training Status	Signoff Date
	Authorized User	Fully Author-ized		complete	
	Restricted User	Task Specific			

By signing off, Users have acknowledged that their participation in the activities described requires that they 1) understand the hazards and controls involved; 2) receive the appropriate training (including On the Job Training) prior to work; and 3) adhere to all appropriate safety procedures during participation.

EXAMPLE

1) Description of Hazard

2) Controls

a) Mitigation of Hazards

b) Personal Protective Equipment

c) Hazardous Material Handling

3) Waste

4) Emergency Procedures

5) Identify Users and Training